Review of J. S. Bell: *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press 1987, pp XII + 212 and D. Murdoch: *Niels Bohr's Philosophy of Physics*, Cambridge University Press, 1987, pp X + 294.

A large number of books have been published during the last few years on ~~the~~ philosophy of quantum mechanics. They divide into two main classes: popular expositions of the 'paradoxes' and attempted solutions, written generally by physicists, and technical treatises on the philosophical problems involved, ~~often involving some quite high-powered mathematics~~ written by that new species of 'academic expert', the philosopher of physics. Much of the impetus for this renewed interest in the interpretative problems of quantum mechanics stems from the seminal work of John Bell – in the 1960s. He challenged the assumptions that lay behind von Neumann's famous proof of the impossibility of hidden variables in quantum theory, augmenting the incomplete description afforded by the quantum-mechanical state vector (or wave function if you prefer ~~in~~ wave-mechanical terminology), but showing that any such 'completed' version of quantum mechanics must necessarily involve a feature of nonlocality, ~~[illegible]~~ of apparently instantaneous action-at-a-distance. This arose from the

Insertion

¥ This inequality was shown by Bell to be a necessary condition that must be satisfied by any ~~local realistic~~ theory incorporating local realism.

who succeeded in showing modulo some very plausible assumptions about the working of their apparatus, that the ~~nonlocal action~~ mysterious nonlocal action would have to be effective at ~~spacel~~ spacelike separation i.e. at superluminal speed of propagation.

violation, predicted by the quantum-mechanical formalism of the famous Bell inequality relating certain correlation coefficients in ~~certain~~ two-particle systems prepared in so-called entangled states typified by the singlet state of two spin-½ ~~photons~~ particles.* During the last fifteen years many experiments have been carried out to test the predicted violation of the Bell inequality culminating in the work of Aspect and his collaborators in Paris. #

It is ironic that Bell's work supplements the Einstein-Podolsky-Rosen proof in 1935 of the incompleteness of the quantum-mechanical formalism, predicated on the absence of action-at-a-distance, by showing that a 'completed' quantum mechanics must itself be nonlocal!

It is a great delight to see all of Bell's papers on the foundations and philosophy of quantum mechanics, many of which were published in rather inaccessible sources, collected together and reprinted by Cambridge University Press. The work of Bell falls into neither of the two classes mentioned at the beginning. It is serious physics rather than popularization, but with none of the finicky logic chopping of the philosophers. Bell always works with the simplest examples, but has an amazing talent for putting his finger right on

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Bell recognizes that an important element of the Bohrian insight remains, namely that measurement results, in general, are a product of both 'system' and 'apparatus', rather than revealing some preexisting property of the 'system'.

II He plays with the idea of an aether, picking out a preferred 'inertial' reference frame but one which is intrinsically unobservable. In a paper entitled 'How to Teach Special Relativity', he emphasizes that this is a 'perfectly' coherent way to understand relativity, following the ideas of Lorentz rather than Einstein.

Bell is generally critical of the Everett–Wheeler many worlds interpretation of quantum mechanics, much espoused these days by cosmologists. He stresses the ambiguity in just when measurements are supposed to take place and the splitting of the universe to occur, and claims that the de Broglie–Bohm approach

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nerve-centre of any argument.

His view, put very simply, is that the orthodox Copenhagen interpretation, with its talk of a 'cut' between subject and object, its privileged role for classical description on the observer's side of the cut, and what Bell describes as its, ~~almost mean~~ (~~according to Bell~~) incompatible 400 doctrine of complementarity should be put aside in favour of the de Broglie–Bohm approach where instead of ~~wave or~~ particle or wave in complementary situations, we have particle and wave; the wave Guides ~~governs~~ the motion of the particle just like ~~an~~ a classical field, ~~but~~ and everything is fully objective and well-defined at all times. ✱ Insertion But we have to bite the bullet and accept ~~face up to~~ the glaringly non-local features of this approach. Although the nonlocality involved is 'non-controllable' and cannot be used to send superluminal signals, there are prima facie difficulties about relativity theory. This 500 is a very active area of research among the philosophers of physics. Bell himself poses the problems in the sharpest possible way without really attempting to solve them. #

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By contrast Murdoch's book attempts a critical assessment of the Bohr interpretation of which Bell is so dismissive. Murdoch gives a gloss on Bohr's writings, showing that experiments discover 'objective' values, rather than

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is a much preferable basis for ~~quantum cosmology~~ the application of quantum mechanics to cosmological problems of the whole universe, where there is in principle nothing 'outside' to play the role of the observer.

creating them which he tries to reconcile with the claim that ~~that~~ quantum-mechanical systems do not have intrinsic properties independently of a measurement context. Murdoch emphasizes the influence of pragmatism on Bohr's philosophical thinking, and downgrades the Kantian elements that ~~[illegible]~~ other writers have discerned.

Murdoch's book is a welcome addition to the rapidly expanding corpus of Bohrian exegesis. He includes discussion of Bell's later work and ~~as a result~~ concludes on balance, "there is no outright victor in the Bohr-Einstein contest"⑤

The two books taken together give an ~~useful~~ exemplary introduction to the ongoing debates. Physicists no longer have any excuse for believing that all questions of interpretation have long been answered and, as Bell puts it, they could fully understand just how if ever they could spare twenty minutes to think about it!

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